Highway-Rail Grade Crossing Safety Study

Texas Eagle

July 14, 2023

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List of Abbreviations

Advance Warning Flashing Signs	AWFS
Advance Warning Signs	AWS
American Railway Engineering and Maintenance-of-Way Association	AREMA
Average Annual Daily Traffic	AADT
Average Daily Traffic	ADT
Bipartisan Infrastructure Law	BIL
Federal Highway Administration	FHWA
Federal Railroad Administration	FRA
Global Positioning System	GPS
Grade Crossing Inventory System	GCIS
Kansas City Terminal Railway	KCT
Location-Based Services	LBS
Manual on Uniform Traffic Control Devices	MUTCD
Missouri Department of Transportation	MoDOT
Property Damage Only	PDO
Railroad Crossing Inventory System	RCIS
Right-of-Way	ROW
Terminal Railroad Association of St. Louis	TRRA
Union Pacific Railroad	UP
United States Department of Transportation	USDOT
Vehicle-Hours Delay	VHD
Vehicle-Miles Traveled	VMT

Executive Summary

In 2023, MoDOT contracted HDR Engineering, Inc. to conduct an evaluation of 98 public highway-rail grade crossings and one (1) pedestrian crossing along the Texas Eagle Amtrak line, which spans the southeastern portion of the state, from St. Louis to the Arkansas border. The purpose of this study was to conduct an independent, objective, and data-driven evaluation of Missouri's highway-rail grade crossings.

STUDY GOALS

The primary goal of the study was to increase public safety by first identifying improvements for the public crossings in this corridor equipped with only passive protection such as crossbucks, yield signs, and stop signs. The next goal was to similarly review the remaining public crossings and make recommendations regarding the implementation of closures/ consolidations, grade separations, or active warning device upgrades at each public vehicular crossing in the corridor.

Table E-1: Five-Year Incident History

Type	Incidents
Fatal	0
Injury	2
Property Damage Only	2
TOTAL	4

The study examined physical crossing attributes, such as the number of tracks, crossing control, roadway alignments, and the surrounding context. It also examined operational data, such as daily train and vehicular traffic volumes, truck traffic, pedestrian activity, incident history (see Table E-1), regulatory train and vehicle speeds.

The study found that many of the crossings were missing traffic control elements that could further promote safety, such as signing, pavement marking, lighting, and active warning devices. The study also found that many crossings had horizontal and vertical elements that could be improved to further promote safety.

RECOMMENDATIONS

Recommendations are divided into four tiers, based on the degree of identified need and the complexity of implementation, to be phased over the next one to three years. Table E-2 summarizes the costs of these recommend improvements per Tier.

Table E-2: Improvement Costs per Tier

Tier	Description	Affected Crossings	Cost
I	Passive public crossings	25	$10,855,000
II	Less complex improvements	78	$2,103,000
III	More complex improvements	27	$8,913,000
IV	Grade separations / studies	6	$13,585,000
TOTAL			$35,456,074

Note: Total Affected Crossings does not tally to 98 due to some crossings having recommendations in multiple tiers.

Twenty-five (25) crossings were identified as passive public crossings and labeled as Tier 1 priorities. Table E-3 provides the locations of these crossings and specifies the recommended improvement at each.

Table E-3: Tier 1 Recommendation Summary

Crossing ID	Highway	City/County	Tier I Recommendation
438543E	County Road 278	Butler/Clay County	Upgrade with Gates and Lights + Illumination
438541R	County Road 276	Butler County	Closure/Consolidation
438540J	County Road 272	Butler County	Upgrade with Gates and Lights + Illumination
438537B	County Road 343	Butler County	Closure/Consolidation
438536U	County Road 350	Butler County	Upgrade with Gates and Lights + Illumination
438535M	County Road 352	Butler County	Closure/Consolidation
438534F	County Road 340	Butler County	Upgrade with Gates and Lights + Illumination
438533Y	County Road 338	Butler County	Closure/Consolidation
438532S	County Road 336	Butler County	Upgrade with Gates and Lights + Illumination
446320J	Johnson Drive	Poplar Bluff	Upgrade with Flashing Lights
445992L	Wilcox Road	Butler County	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
446052B	County Road 349B	Wayne County	Upgrade with Gates and Lights + Advance Warning Signs
446038F	Black River Road	Wayne County	Upgrade with Gates and Lights + Illumination
446051U	County Road 349	Wayne County	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
445910C	County Road 147	Iron County	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
445920H	Sabula Road	Iron County	Upgrade with Gates and Lights + Illumination
445921P	Warren Hill Road / County Road 124	Iron County	Upgrade with Gates and Lights + Illumination
445937L	Industrial Drive	Ironton	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
445949F	Middlebrook Road	Pilot Knob	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
446420N	Pine Street	Irondale	Upgrade with Gates and Lights + Illumination
446421V	West Ash Street	Irondale	Upgrade with Gates and Lights + Illumination
446422C	North Oak Street	Irondale	High-Security Gate
446454H	Miller Street	DeSoto	Upgrade with Gates and Lights
803352A	Dock Street	St. Louis	Upgrade with Gates and Lights + Other
803351T	Buchanan Street	St. Louis	Upgrade with Flashing Lights

OUTCOMES

The study found that the risk of incidents along the corridor could be reduced by up to 12 percent (see Table E-4). This number could be potentially understated, as risk reduction for certain improvements cannot be quantified by industry standard methodologies.

Table E-4: Corridor Risk Reduction

Tier	Risk Reduction
I	10.3%
II	11.9%
III	12.4%

NEXT STEPS

A number of key steps, listed below, will be required to finalize and implement the recommendations made as part of this study. Necessary public engagement will follow during project development but will not affect the findings of this study.

- Tier I Field Diagnostic Evaluations (June 2023)
- Planning and Construction Coordination for Tier I Safety Improvements (Summer 2023 – Spring 2024)
- Tier II-III Diagnostics and Coordination (Fall 2023 – 2024)
- Coordination of Planning and Study Activities for Tier IV Improvements (2024-2026+)

Introduction and Study Overview

PROJECT SCOPE

This study evaluates the public highway-rail grade crossings along Amtrak's **Texas Eagle** route, one of the state's three passenger rail corridors.

Within the state of Missouri, the Texas Eagle (see graphic at right) extends north-south in Missouri for approximately 185 of its total 1,306 miles from St. Louis to the southern border with Arkansas. The route provides service of one (1) train daily in either direction. Pre-pandemic ridership averaged nearly 325,000 riders annually but fell to an average of 175,000 in 2020 and 2021[1]. The full extents of this route connect Chicago with Los Angeles, providing service within the states of Illinois, Missouri, Arkansas, Texas, New Mexico, Arizona, and California.

The majority of this Amtrak route within Missouri runs on Union Pacific (UP) tracks with a short stretch of operation on Terminal Railroad Association of St. Louis (TRRA) trackage before crossing the Mississippi River in St. Louis.

The purpose of this study was to conduct an independent, objective, and data-driven evaluation of Missouri's highway-rail grade crossings. The first stage of plan development involved an in-depth data collection effort and inventory of each of 98 highway-rail grade crossings along the route to identify existing infrastructure (warning devices), accident history, and potential hazards, including sight obstructions.

The first priority of the study was to identify and review the public crossings in this corridor equipped with only passive protection including stop signs, yield signs, and crossbucks. The goal was to increase public safety by identifying improvements such as closures/consolidations, grade separations, or active warning device upgrades for all public passive crossings of passenger rail corridors. The next stage of the study was to identify additional safety improvements at each of the remaining crossings in the corridor. Improvement options were identified based on safety benefits, community impacts, changes to travel patterns/accessibility, and potential for right-of-way (ROW) takings/displacements. Each improvement recommendation was categorized according to a tiering system based on the approximate time to implement. High-level cost estimates were developed for each of the improvement options as well as estimates of the reduction in annual crossing crashes.

[1] Based on data contained in https://www.railpassengers.org/site/assets/files/3463/56.pdf, retrieved 6/13/2023

PROJECT HISTORY

Highway-rail grade crossing safety has long been a priority for MoDOT, railroads operating in the state, local roadway authorities, and other stakeholders. Safety at public highway-rail grade crossings is the purview of MoDOT's Multimodal Operations Division-Railroad Section. This group manages the crossing safety improvement program and utilizes rail safety inspectors to continually monitor compliance with state and federal guidelines and to conduct rail safety education and outreach. The Missouri Highway-Railroad Crossing Safety Program is managed as part of the Federal Highway Administration's (FHWA) Section 130 Program and is the primary source of funding for MoDOT's grade crossing safety improvement projects. The program provides approximately $6 million per year. Additionally, MoDOT receives another $1.5 million in funding through the State's Grade Crossing Safety Account[2], which is funded through a 25-cent tax on motor vehicle registrations and renewals.

Over the last few decades, Missouri has made great strides in improving highway-rail grade crossings safety throughout the state. Between 1976 and the present day, Missouri has reduced the number of annual rail collisions by 87 percent, reduced rail fatalities by 98 percent, and reduced rail injuries by 82 percent (Figure 1).

Figure 1. Missouri Rail Crossing Progress Since 1976

Rail Collisions	Rail Fatalities	Rail Injuries
REDUCED 87%	REDUCED 98%	REDUCED 82%
Since 1976	Since 1976	Since 1976

SOURCE: MODOT RAILROAD SAFETY

However, this trend of progress has not been without occasional setbacks. On June 27, 2022, an Amtrak train traveling eastbound on the Southwest Chief line collided with a dump truck at a crossing near Mendon. The force of the crash derailed seven of the eight passenger rail cars. It resulted in injury to 150 passengers and the deaths of four (4) individuals, including the dump truck driver. The crossing at which this collision took place was not equipped with active warning devices (typically automatic gates and/or flashing lights). As a direct response to this crash, Missouri Governor Mike Parson requested a new line item in the fiscal year 2024 budget "to begin updating railway crossings to modern-day safety standards all across our state."[3] The legislature approved $50 million toward this goal.

This study is the first step in the process of using that funding to install additional active warning devices and other safety improvements at highway-rail grade crossings along the three passenger rail corridors in Missouri.

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[2] https://www.modot.org/railroad-safety, retrieved 6/13/2023

[3] Parson, Michael L. 2023. "Missouri State of the State Address". Delivered at Jefferson City, January, 18, 2023.

PROJECT SCHEDULE

Owing to the timing of the recent Amtrak derailment (June 27, 2022) and appropriated funding from Missouri, MoDOT put together a plan to independently analyze public highway-rail grade crossings with respect to active Amtrak operations on three corridors.

- In February 2023, MoDOT solicited bids for the corridor studies, and engaged the Public Projects groups at two Class I railroads (UP and BNSF Railway) for their assistance on project implementation.
- In March 2023, consultants began working on the corridor studies.
- In May 2023, the MoDOT's Multimodal Operations Division-Railroad Section and its consultant teams presented initial findings to MoDOT's Executive Staff and Director. Also starting in May 2023 was crossing diagnostic work, which included the participation of UP and BNSF Railway's Public Project groups. These diagnostics will inform future project development.
- In June 2023, draft and final reports and corresponding recommendations were delivered to MoDOT staff for review and implementation.
- Tier I recommendations are priority projects with the intent of being completed within twelve (12) months, or by June 2024 – subject to railroad design processes, contractor availability, and other planning needs.
- Tier II through Tier IV projects have a longer lead time due to complexity in design (railroad or roadway), have the potential to require additional study and refinement.

Data Collection

In order to evaluate the existing conditions at each of the highway-rail crossings, an extensive inventory was created. Key elements collected include types of existing warning devices, highway traffic volumes and speeds, train volumes and speeds, crash history over the past ten (10) years, geometric configuration, and crossing surface material. Key sources of this data are described below in the sections below.

MODOT GRADE CROSSING INVENTORY SYSTEM (RCIS)

The MoDOT RCIS was used as the primary data source for highway-related characteristics such as Annual Average Daily Traffic (AADT), speed limit, and roadway characteristics at grade crossings. While much of this data can also be found in the FRA inventory (described later), MoDOT staff are able to more frequently and accurately update the RCIS based on MoDOT studies, collaboration with roadway jurisdictions, construction projects, field reviews and diagnostics, and other investigations. This inventory was considered the most logical starting point for developing the crossing inventory for the Texas Eagle corridor.

FRA GRADE CROSSING INVENTORY SYSTEM (GCIS)

The Federal Railroad Administration GCIS was used as the primary data source for rail-related information such as train speeds and volumes at each crossing, as well as historic highway-rail crash data. The GCIS was also used as a supplemental resource for highway-related characteristics. The data in this inventory is routinely updated by the primary operating railroads, MoDOT, and other agencies. It was assumed for this project that the rail-related information included in the FRA GCIS was more likely to be accurate compared to the same information in the MoDOT RCIS.

FIELD / PHOTO DATA COLLECTION

Google Maps Aerial Imagery and Google Street View were utilized to verify data collected from the RCIS and GCIS sources. In addition to verifying data collected from the RCIS and GCIS, information on crossing geometry, illumination, traffic control devices, and warning signage was collected. For locations that did not have recent aerials or current Street View images, or which required validation of other crossing data, the study team conducted field visits to take photos and verify existing conditions. In April 2023, approximately 27 crossings were visited in person along this route.

STREETLIGHT

Streetlight Data is a ”Big Data” source that utilizes GPS, LBS (or location-based services), and connected vehicle data to estimate AADT, origin-destination and routing data, turning movement counts, demographics, and other metrics including vehicle-miles traveled (VMT) and vehicle-hours of delay (VHD). MoDOT maintains a statewide license to the StreetLight Platform for use in transportation studies and planning exercises such as this. For purposes of this study, StreetLight data was used primarily for AADT validation and the estimation of bicycle, pedestrian, and truck activity levels at each crossing.

REPLICA

Replica is a “Big Data” resource, similar to StreetLight Data, that can be used to estimate origin-designation flows along study network links. HDR, the consulting firm that supported MoDOT on this study, maintains a nationwide license for use of the platform. For this study, Replica was used primarily as a supplemental data source for pedestrian and bicyclist activity levels and for the identification of origins and destinations of highway users that travel over each crossing. These user travel sheds were used to estimate the potential rerouting effects of crossing closures.

HERE ROUTING API

HERE Technologies is a location data and technology company with multiple geospatial analysis capabilities. The HERE Routing API was specifically used for this analysis to calculate the estimated route used by highway crossing users based on the origin and destination data collected from Replica and StreetLight. The HERE API allows for the calculation of mode-specific (e.g., passenger vehicle, truck, pedestrian, bicyclist) routing between two points. HERE was used to calculate closure-induced delay by (a) using Replica to generate the estimated start and end point of trips passing over each crossing, (b) using HERE to estimate the travel time for each trip with the crossing open, (c) using HERE to estimate the travel time for each trip assuming that the crossing in question is closed, and (d) calculating the difference in vehicle-hours between (c) and (b) to estimate total vehicle-hours of delay and average delay per vehicle.

Existing Conditions

Table 1 summarizes the number of each basic type of crossing (at-grade or grade-separated) and public vs. private ownership. Table 2 summarizes the types of warning devices present for each of the public grade crossings. The warning device types are also mapped in Figure 2.

Table 1. Crossing Type (All Crossings)

Type	At-Grade	Grade-Separated
Public	98	86
Public Pathway (Incl. in Public)	1	-
Private	96	3
TOTAL	**195**	**89**

Table 2. Warning Devices (Public Grade Crossings)

Warning Type	# Crossings
Passive (Stop/Yield/Crossbucks)	25
Flashing Lights Only	9
Gates & Flashing Lights	64
TOTAL	**98**

Figure 2. Existing Control Type at Public Highway-Rail Grade Crossings

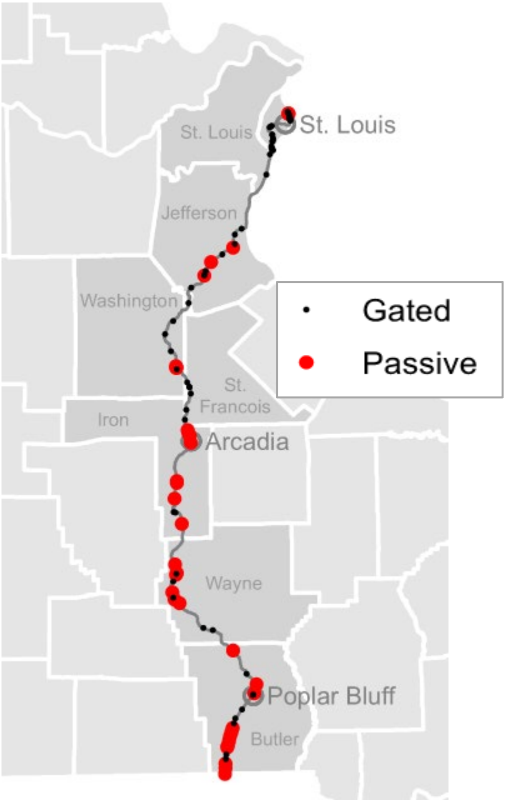


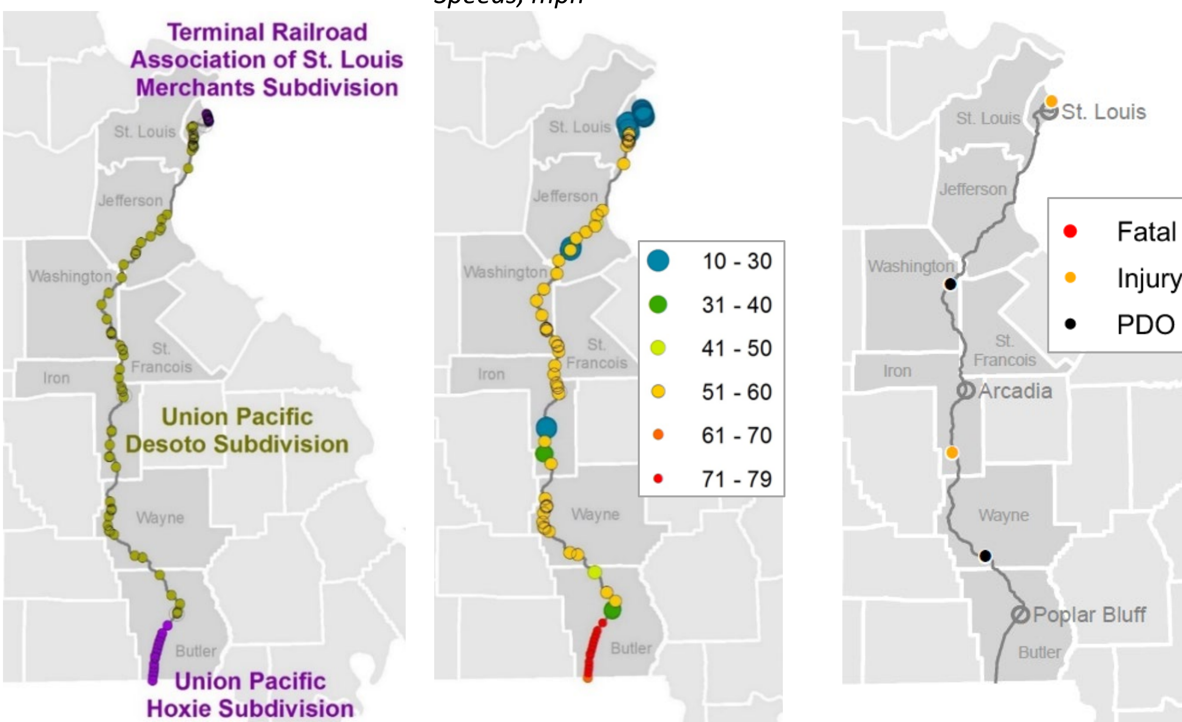
Figure 3 maps the relevant railroad and subdivision for each highway-rail grade crossing along the corridor. The majority of the corridor – 83 public highway-rail grade crossings – is on UP tracks; the remaining 15 crossing are on tracks owned by the TRRA.

Figure 3 also maps maximum allowable train speeds at each highway-rail grade crossing along the corridor. Speeds range from 10 mph to 79 mph.

Figure 3 also maps and summarizes incidents along the route for a five-year period. No fatal incidents have occurred, and only two (2) injury incidents and two (2) property-damage-only incidents were recorded.

Figure 3. Texas Eagle Route Characteristics

Track Ownership and Subdivision | *Maximum Allowable Train Speeds, mph* | *Five-Year Incident History*



Recommendations

Based upon the data collected and the assessed needs determined at each of the crossings, the study team identified the types of improvements that would be applicable to each crossing, how those improvements would affect the crossing and surrounding area, and which improvements should be prioritized. All of these elements were considered when final recommendations were developed.

TYPES OF IMPROVEMENTS

The types of improvements considered range widely in terms of cost, effectiveness in addressing safety needs, and appropriateness to the local surroundings. For example, a full closure could be fairly inexpensive (if an adequate detour route were available) and would be very effective at addressing safety but would typically only be appropriate in locations with very low highway traffic volumes. At the other end of the spectrum, a grade separation would be equally effective in improving safety (from the standpoint of eliminating the possibility of rail/vehicle collisions) and would be appropriate for locations with higher traffic volumes but would be significantly more expensive. Each of the improvement types considered in this study are described in the sections below. Estimated costs are given in 2023 dollars.

Closure/Consolidation

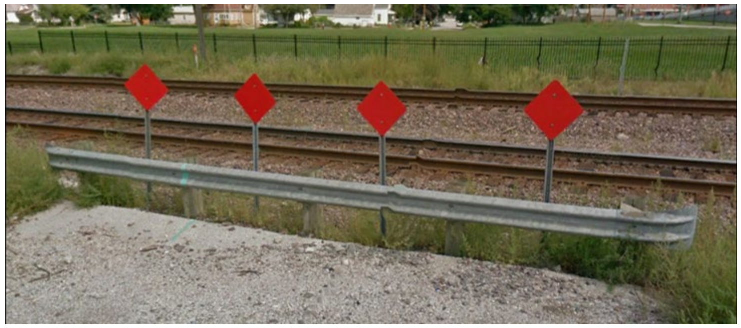
A common mantra of the FRA is, "The safest grade crossing is one that doesn't exist." Closing crossings can reduce the potential for incidents to nearly zero and is typically the most cost-effective way to improve safety along a rail corridor. The benefits of consolidating redundant grade crossings are:

- Fewer intersections at which collisions between motor vehicles or pedestrians and trains can occur
- Removal of a potential safety hazard at a cost that is often only a fraction of the cost of active warning devices
- Redirection of limited resources to the remaining crossings that have the greatest public necessity
- A reduction in the number of highway-rail grade crossings that may need costly improvements or grade separation in the future to accommodate high-speed rail operations.

The method for closure varies depending on the specific needs for the crossing being closed. The rail crossing surface and roadway surface within the railroad ROW must be removed; this work must be coordinated with the railroad. Modifications to the track itself, such as removal of crossing surface and approaches, are typically performed by the railroad's own forces – who may also opt to perform the pavement and grading removals within their ROW. In some cases, vegetation may be planted. Signage and other improvements outside of the railroad ROW are typically the responsibility of the agency owning the roadway. Physical barriers (Figure 4) are designed in compliance with *Manual on Uniform Traffic Control Devices* (MUTCD), Traffic Control Devices Handbook 2nd Edition, and host railroad standards / guidance. Roadway approaches are then realigned with cul-de-sac turnarounds, hammerhead intersections, or other configurations allowing for larger vehicles to reverse direction. In some cases, new roadway connections can be implemented to provide access to maintain key roadway connections. However, these additional roadway connections carry increased costs and typically require substantial ROW acquisition to become feasible. Fencing should also be considered in areas where the closure has the potential to encourage trespassing.

The cost to close a crossing has a wide range, dependent on the scope of associated roadway work, but basic closures identified in this study can typically be implemented for less than $30,000. In the case of any crossing necessitating roadway modifications, the cost to close a crossing could increase to millions of dollars. Specific information on the types of proposed roadway modifications and costs are given in sub-section "*Major Roadway Improvements.*"

Figure 4. Standard Closure Barrier

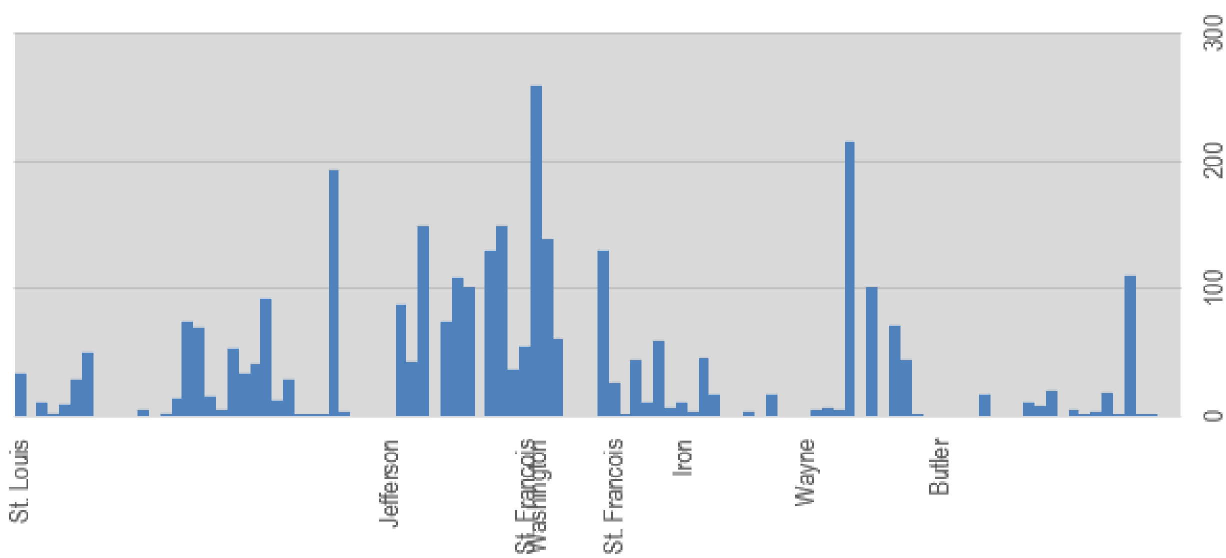


USDOT's Section 130 program includes provisions for the use of program funds as closure incentive funding. Under the recent Bipartisan Infrastructure Law (BIL) federal transportation bill, this amount was increased from $7,500 to $100,000 per crossing, subject to matching funding from the railroad.

The safety benefit of crossing closures is assumed to be a nearly 100 percent reduction in risk at the crossing being closed. Note that adjacent crossings, which typically experience increased detour traffic from a closure, will have slightly elevated risk levels. However, in most cases, this represents a minimal increase from current levels.

For each crossing, the average daily delays that would result from re-routing motorists – if the crossing were to be closed – were estimated using the Replica and HERE data described previously. Figure 5 displays a graphical summary of these predicted delays for the corridor. There is no pre-determined threshold for determining what levels of delay are "acceptable." However, for this study, closures and consolidations were generally only recommended when the estimated daily vehicle-hours of delay were below 10. The re-routing delays were considered when recommending potential closures.

Figure 5. Predicted Closure Detour Delay per Crossing, Vehicle-Hours (North → South)



Automatic Gates and Flashing Lights

Found at many railroad-roadway crossings, gates and flashing lights are active traffic control devices that include components to detect trains approaching the crossing. If a crossing includes automatic gates and flashing lights, it is said to be an "actively" controlled crossing. When a train has been detected, lights will begin to flash and bells will begin to sound for a predetermined interval prior to the arrival of a train, warning drivers that a train is approaching. A motorized drive will lower a retroreflectorized red-and-white gate with lights to a horizontal position at a shorter predetermined interval before the arrival of the train, physically restricting vehicular and pedestrian access. For multi-lane or profile-restricted roadways, an overhead metal-frame cantilever element is often used to support a second set of flashing lights for added emphasis or to improve visibility to those in the middle lane. Missouri Statute 304.035 regulates drivers approaching automatic gates and flashing lights under penalty of a Class C misdemeanor for failure to comply.

Figure 6. Automatic Gates and Flashing Lights, Standard and Cantilevered Examples

Per the stated study goals (see the "Project Scope" section), active warning devices such as automatic gates and flashing lights are recommended for all public passenger rail crossings in Missouri that are currently controlled by non-active traffic controls and are not being recommended for closure. For this study, the cost for a system of automatic gates and flashing lights controlling two roadway approaches is estimated to be $400,000. This cost can be impacted by factors including the availability of power, the proximity of adjacent crossings, and the number of tracks at the crossing. Costs will be further refined as projects advance in planning and design.

The safety benefits of automatic gate and flashing light installation have been quantified by the FRA in the GradeDec Reference Manual and vary based on the number of trains per day, the number of tracks at the crossing, and the existing warning devices (Table 2). More information on risk reduction and FRA risk modelling used is provided in section "*Safety* Outcomes." Twenty-five (25) public crossings in the Texas Eagle corridor are not currently equipped with active warning devices.

Table 3. Gates and Flashing Lights Risk Reduction

Trains/Day	≤10	≤10	> 10	>10
Track Configuration	Single	Multiple	Single	Multiple
Control Change				
Passive to Flashing Lights	75%	65%	61%	57%
Passive to Lights and Gates	90%	86%	80%	78%
Flashing Lights to Gates	89%	65%	69%	63%

Source: FRA GradeDec Reference Manual

Four-Quadrant Gates

Four quadrant gates function similarly to the standard automatic gates and flashing lights described above. However, these systems include two additional gates which fully block access to the crossing when in the lowered position. These systems are useful in cases where motorists have historically been recorded circumventing the gates. However, they are also substantially more expensive to install and maintain, require more complex infrastructure, and increase delays due to added warning times need to successfully activate. Much of the increased installation and maintenance costs is related to the in-pavement vehicle detection systems that are typically used to determine whether the exit gates can be lowered without trapping highway users on the crossing surface. Due to these concerns, no four-quadrant gates systems have been recommended at any Texas Eagle crossing. However, other engineered systems can be employed to help channelize and direct vehicular traffic, such as non-mountable curb islands or non-traversable medians. These systems are much more cost-effective and have been included in some crossing recommendations.

Figure 7. Four-Quadrant Gates

Flashing Lights

Historically, active warning devices have sometimes been installed without gate arms. Some of the reasons for this previous approach have been concern about false activation of the gates potentially blocking traffic, and increased installation and maintenance costs for the gate arms. In recent years, the industry standard has shifted toward a near universal recommendation of including gates and flashing lights together as described above. However, individual crossing characteristics may dictate that flashing lights-only are a reasonable option.

Three crossings in the Texas Eagle Corridor include recommendation options for flashing lights only:

- **Johnson Road (446320J) in Poplar Bluff:** At this location, this eastern side of the crossing is an open yard for the city Public Works Department. This configuration makes standard gate installation impossible without substantially changing access to the facilities on the east side of the crossing.
- **Buchanan Street (803351T) in St. Louis:** The proximity of a salt storage and distribution facility adjacent to the crossing greatly increases the potential for false activation of the crossing circuits.
- **Thompson Lane (445933J) in Arcadia:** The configuration of the crossing layout makes the installation of gate arms infeasible.

Some crossings also include recommendations for sidelights. These are additional flashing light pairs installed on existing signal masts that are directed toward side roads or other key approaches.

Pedestrian Gates and Flashing Lights

In urban environments where a sidewalk exists next to the roadway at a railroad-highway grade crossing, the sidewalk is often positioned to allow the automatic gates to cover both the road and sidewalk. In cases where the vehicle gate does not cover the sidewalk, a smaller gate may be installed to provide additional active controls for the sidewalk, as seen in Figure 8**.** A single pedestrian crossing gate is estimated to cost $100,000. Pedestrian gate and flashing light systems have been recommended where high pedestrian activity was deemed to justify the cost of installation.

Figure 8. Pedestrian Gates and Flashing Lights-Only Systems

Bells

Bells are audible warning devices that sound when the signal system is activated by an approaching train. Standard installation includes one bell per crossing placed on the top of one of the signal masts. Bells activate even in designated quiet zones where train horns are not sounded. While not called out as specific recommendations within this report, the placement and use of bells should be discussed during diagnostic meetings to determine best placements and whether more than one bell is warranted based on higher pedestrian activity levels or other factors.

Public-to-Private Crossing Conversion

Private crossings are intended for use only by property owner(s) and provide access only to privately-owned locations or facilities. As opposed to public crossings, private crossings are not maintained by MoDOT or local road authorities. There are a number of locations in this corridor that are categorized as public crossings – because they are located on publicly maintained roadways – but in practice they function more like private crossings (e.g., providing access to a single house, or providing access to agricultural areas with no outlet). At locations like these where average daily traffic is very low and public use is limited, the installation of active warning devices may not be warranted.

Figure 9. Private Crossing Signage

An approach proposed by this study is to consider the conversion of these crossings to the private crossing category. This would require signed agreements between the railroads and the local property owner(s) served by the crossing. In many cases, this would also include the jurisdictional transfer of roadway segments to private ownership. While this approach may not always be feasible given the complexity of negotiating between multiple agencies and property owners, it should be pursued before defaulting to the more costly options of gate and flashing light installation. At crossings where public-to-private conversion is implemented, appropriate signage, meeting MUTCD and FRA requirements, must be installed, an example of which is shown in Figure 9.

Signing and Pavement Markings

Advance warning, regulatory, and emergency notification signs, along with pavement markings, are a very common form of railroad-roadway traffic control. A crossing that has no automatic gates and/or flashing lights and only signage, is considered "passively" controlled. Even in locations where a crossing may use active controls, passive control devices – such as advance warning signs and pavement markings – are required by the MUTCD at all grade crossings, except in special circumstances.

Advance Warning Signs (AWS): Advance warning signs are used to convey information to drivers. Figure 10 shows AWS commonly recommended in this Corridor Safety Improvement Plan. A W10-1 is required to warn drivers that they are approaching a crossing and is placed at a distance determined by the posted speed limit of the road. A W10-4 is used on a roadway that runs parallel to track(s). A W10-5 is used to inform larger vehicles of a humped crossing, which may pose a risk of high-centering. A W10-11

is used to inform drivers of limited storage space between an intersecting roadway and the track. A W10-9 is used to supplement a W10-1 within quiet zones where there is authorization for trains to not sound a horn – typically implemented in dense, urban environments. This list and descriptions of signage reflects the most common signage recommended and is not intended to be comprehensive of all signage recommended in this study. The cost of AWS is estimated to be $500 per sign.

Figure 10. Examples of Advance Warning Signs used in Corridor Safety Improvement Plan

Advance Warning Flashing Signs (AWFS): These enhanced signs are most often used in rural areas with little to no illumination along the roadway. Especially on gravel roads with no pavement markings, W-10 series advance warning signs equipped with flashers have generally been found to improve performance compared to signs alone. There are two common methods of adding flashers to an advance warning sign: placing LEDs around the edge of the sign or utilizing a flashing beacon. The lights have the potential to be powered by an attached solar panel, so a nearby power source may not be required. Both types are shown in Figure 11. The cost of AWFS is estimated to be $2,000 per sign.

Figure 11. Examples of Advance Warning Signs with Flashers

Pavement Markings: White retroreflectorized pavement markings are required in advance of gated highway-rail grade crossings and consist of an "X", the letters RR, a no-passing marking (typically centerline markings), and transverse lines. Pavement markings should be placed directly adjacent to advance warning signs, as shown in Figure 12. The cost of pavement markings is estimated to be $2,000 per approach.

Figure 12. Pavement Markings

Illumination

Street lighting located near crossings can enhance drivers' ability to recognize the presence and occupancy status of a rail crossing. When a power source and/or streetlights are already located nearby, illumination can provide a low-cost option to improve the safety of a crossing. Four luminaires mounted on two poles are typically required to provide 100 feet of coverage on each approach. While the cost to light a crossing can vary depending on the existing electrical infrastructure, it is estimated at $10,000 per approach for purposes of this study.

Major Roadway Improvements

Most improvement options in this study can broadly be generalized as traffic controls or enhancements to the visibility of traffic controls. However, one category of options consists of improvement to the roadway itself. There are five broad sub-categories of roadway improvements: vertical re-profiling, non-traversable medians, horizontal re-alignment, closure re-alignment, and curb and gutter.

Vertical Re-Profiling: Humped crossings exist when the elevation of the track creates a steep grade on an approach. Humped crossings present a very serious risk, as low trailers or heavy-duty vehicles may become immobilized at the crossing. The American Railway Engineering and Maintenance-of-Way Association (AREMA) *Manual for Railway Engineering* recommends that the crossing surface be in the same plane as the top of rails for two (2) feet on either side of the edge-of-track and the surface of the roadway be not more than three (3) inches higher or lower than the top of the rails at any point from 30 feet from the edge-of-track.

Figure 13. Example of a Humped Crossing

The cost to reprofile vertical grades is estimated to be $50,000 per crossing at a conceptual level, though further study and detailed engineering analysis is required to refine costs for roadway re-profiling.

Non-Traversable Medians: While driving around gates is illegal, according to FRA incident data, this infraction represented nearly 10 percent of Missouri grade crossing incidents from 2016-2020. Non-traversable medians are one method of physically preventing drivers from driving around gates. For this study, medians have only been recommended in urban environments. The cost to add medians is estimated to be $300 per linear foot at a conceptual level.

Figure 14. Non-Traversable Median

Reflectorized tubular channelization devices are an alternative option that carry similar risk reduction benefits as medians but are more susceptible to damage and require more frequent maintenance. However, they are a viable option in scenarios where narrow roadway width limits the ability to install medians, and in locations where higher roadway speeds could cause a greater likelihood of vehicle damage. The determination of medians vs. channelization devices will be discussed and finalized during diagnostic reviews to take place at the conclusion of this study.

Horizontal Crossing Re-Alignment: It is generally desirable that roadways should intersect railroad tracks at a 90-degree angle. Skewed crossings inhibit a driver's ability to view both roadway and railway traffic. The higher the skew, the higher the risk to drivers. Generally, adjusting roadway horizontal alignments can be expensive, depending on the complexity of road geometries involved. Considering the cost involved, horizontal alignment has been recommended sparingly in this study. The cost to realign roadway is estimated to be $400 per linear foot.

Closure Re-Alignment: To maintain access to residents or businesses after a crossing has been closed, some closures may require that new roadways be built, or existing roadways be re-aligned. The estimated cost to re-align roadways post-closure is estimated to be $400 per linear foot.

Curb and Gutter: Some roadway improvements require new curb and gutter installations. The estimated cost to install new curb and gutter is estimated to be $50 per linear foot.

Traffic Signal Preemption

Preemption involves a train-activated timing sequence used to change traffic signal indications prior to the arrival of a train. According to the MUTCD, preemption circuitry should be installed at any signalized intersection within 200 feet of a crossing. The primary function of preemption timing is to ensure that a queued vehicle at a red light, which may have stopped on the railroad tracks, is given enough time to clear the tracks prior to gates closing and the arrival of a train. Preemption may also be used to restrict movements from the traffic signal, toward the tracks, when a train is approaching or is within the crossing. The cost to add preemption circuitry to a signalized intersection is estimated to be $100,000.

Blank-Out Preemption Sign: When signal preemption is activated by railroad preemption, the act of railroad preemption will disrupt standard scheduled traffic control cycles, causing the associated crossing's intersection's traffic signals to be out of cycle with the rest of the greater traffic control system. A crossing intersection's traffic controls will need to transition to re-align with the rest of the control system, these post-preemption cycles are known as "dwell" or "limited phase" cycles. An additional sign restricting movements assists during these transitionary cycles. The estimated cost to add a blank-out preemption sign to signal preemption is to signal preemption is estimated to be $75,000.

Grade Separation

Grade separation is a method of vertically aligning a junction of roadway and railway at different heights (grades) so that they will not cross. Typically, this occurs by means of an overpass or underpass. Grade separation can be very costly and time-consuming, though it can offer several major benefits:

- Increased roadway capacity and uninterrupted flow
- Increased safety for all crossing users
- Reduced vehicle-train conflict and delays

Due to the high cost (which would need to be justified by large benefits), this improvement was considered as a “last resort” in this study and has only been recommended at one crossing. The cost to grade separate can range from $10-20 million, though a separate study would be required to arrive at an accurate estimate. The cost for a grade separation engineering study has been estimated to be $350,000.

Security Gates

Security gates act as quasi-closures. In cases where security gates are presented as an option, crossing infrastructure is assumed to be retained and maintained. Security gates allow for flexible roadway access in cases where full closure of a crossing could introduce safety concerns, such as eliminating a secondary access point to properties during extreme weather events. The cost to install a security gate is estimated to be $5,000 to $10,000, based on UP standards.

Figure 15. Security Gates

Other Recommendations

Occasionally, crossings require other specific improvements that don’t fit into the previously described improvement categories.

Sidewalk Extensions: Some existing crossings with high pedestrian activity may not have a sidewalk through the crossing. In these instances, sidewalk extensions have been included as options in this study. The estimated cost to extend a sidewalk through a crossing has been estimated to be $70 per square yard.

Automatic Gate Relocation: In one instance, the automatic gate system in De Soto controls two mainline tracks but not an adjacent spur-track. To reduce risk and better control the crossing, the study recommends relocating one of the gates. The cost to relocate an automatic gate has been estimated to be $100,000.

ADA Pavement Extension: Pedestrian crossings should be accessible to all potential users. The Texas Eagle corridor has only one (1) pedestrian crossing, which was evaluated for ADA accessibility and determined to need no further improvements. The cost to upgrade this crossing to ADA compliance is estimated to be $4,000 per linear foot.

Fencing: At Amtrak stations that handle high pedestrian activity, or at closures that require additional separation, fencing has been recommended. The cost to install fencing has been estimated to be $30 per linear foot.

Drainage: Culverts to maintain drainage requirements may be necessary in the case of vertical re-profiling. The price to install a galvanized steel corrugated metal pipe is estimated to be $100 per linear foot.

Signal Study/Intersection Control Evaluation: In some instances, an unsignalized roadway intersection adjacent to a highway-rail grade crossing may have safety impacts on the crossing itself. Vehicles approaching a roadway intersection on the far side of a grade crossing may stop their vehicle foul of the tracks while queued at the intersection. In these situations, the vehicles may become trapped on the crossing as a train approaches. These recommendations include the evaluation of existing or proposed traffic signal systems that could improve the flow of traffic over the crossing.

Corridor Study: At some locations, additional study of localized site conditions, traffic circulation, and other factors may be warranted within more localized corridor study areas. In all cases, these are designated as Tier IV recommendations.

TIERED IMPROVEMENT STRATEGY

For each crossing, up to three improvement options were developed. The options included the improvement types listed in the previous section. For some crossings, options were mutually exclusive (for example, a closure vs. installing gates and lights). For some, options were independent but potentially groupable (for example, improving a vertical profile and installing pavement markings).

At each crossing, the various improvement options were categorized into one of four tiers. These tiers are based primarily on the approximate installation time assumed for different improvement types and also on the complexity and coordination required of the proposed improvements. Multiple options at a given crossing could be included in a single tier. The rationale for the Tier assignments is described below. Figure 16 maps the crossings with improvements for each Tier.

Tier I

The sole focus of Tier I is passive public crossings in the corridor. Per the study goals described in the introduction, MoDOT seeks to close, grade separate, or install active warning devices at all passive public crossings in the three passenger rail corridors.

Improvements to these crossings are considered to be the highest priority. Tier I improvements have been identified at 25 crossings (see Table 4), at a total cost of $10.9 million. Tier I improvements are intended to be implemented within 12 months.

Note that in some cases, the installation of Tier I improvements prior to the implementation of Tier II-IV improvements may incur additional project costs at individual crossings that are difficult to quantify. For example, if gates and flashing lights are installed as a Tier I recommendation, the future implementation of a Tier II vertical profile improvement may require the relocation or reinstallation of the gate masts and other associated infrastructure.

Table 4. Tier I Recommendation Summary

Crossing ID	Highway	City/County	Tier I Recommendation
438543E	County Road 278	Butler/Clay County	Upgrade with Gates and Lights + Illumination
438541R	County Road 276	Butler County	Closure/Consolidation
438540J	County Road 272	Butler County	Upgrade with Gates and Lights + Illumination
438537B	County Road 343	Butler County	Closure/Consolidation
438536U	County Road 350	Butler County	Upgrade with Gates and Lights + Illumination
438535M	County Road 352	Butler County	Closure/Consolidation
438534F	County Road 340	Butler County	Upgrade with Gates and Lights + Illumination
438533Y	County Road 338	Butler County	Closure/Consolidation
438532S	County Road 336	Butler County	Upgrade with Gates and Lights + Illumination
446320J	Johnson Drive	Poplar Bluff	Upgrade with Flashing Lights
445992L	Wilcox Road	Butler County	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
446052B	County Road 349B	Wayne County	Upgrade with Gate and Lights + Advance Warning Flashing Signs
446038F	Black River Road	Wayne County	Upgrade with Gates and Lights + Illumination
446051U	County Road 349	Wayne County	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
445910C	County Road 147	Iron County	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
445920H	Sabula Road	Iron County	Upgrade with Gates and Lights + Illumination
445921P	Warren Hill Road / County Road 124	Iron County	Upgrade with Gates and Lights + Illumination
445937L	Industrial Drive	Ironton	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
445949F	Middlebrook Road	Pilot Knob	Upgrade with Gates and Lights + Illumination + Advance Warning Flashing Signs
446420N	Pine Street	Irondale	Upgrade with Gates and Lights + Illumination
446421V	West Ash Street	Irondale	Upgrade with Gates and Lights + Illumination
446422C	North Oak Street	Irondale	High-Security Gate
446454H	Miller Street	DeSoto	Upgrade with Gates and Lights
803352A	Dock Street	St. Louis	Upgrade with Gates and Lights + Other
803351T	Buchanan Street	St. Louis	Upgrade with Flashing Lights

Tier II

Tier II covers crossings and improvements that aren't included in Tier I, but that are less complex than Tier III to implement. For this crossing study, improvements were aggregated into "roll-up" categories, and for the tiering, these categories were assigned either Tier II or III dependent on their complexity. Table 5 shows how they were assigned. Using this methods, Tier II improvements have been identified at 78 crossings, at a cost of approximately $2 million. Tier II improvements are intended to be implemented in less than 18 months.

Table 5. Differentiation of Tiers II & III

Type of Improvement	Tier II	Tier III
Upgrade with Gates and Lights		X
Roadway Modifications		X
Non-Traversable Medians	X	
Advanced Warning Flashing Signs	X	
Illumination	X	
Traffic Signal Preemption		X
Advanced Warning Signs	X	
Pavement Markings	X	
Blank-Out Preemption Sign	X	
Public-to-Private Conversion	X	
High-Security Gates	X	
Others	X	

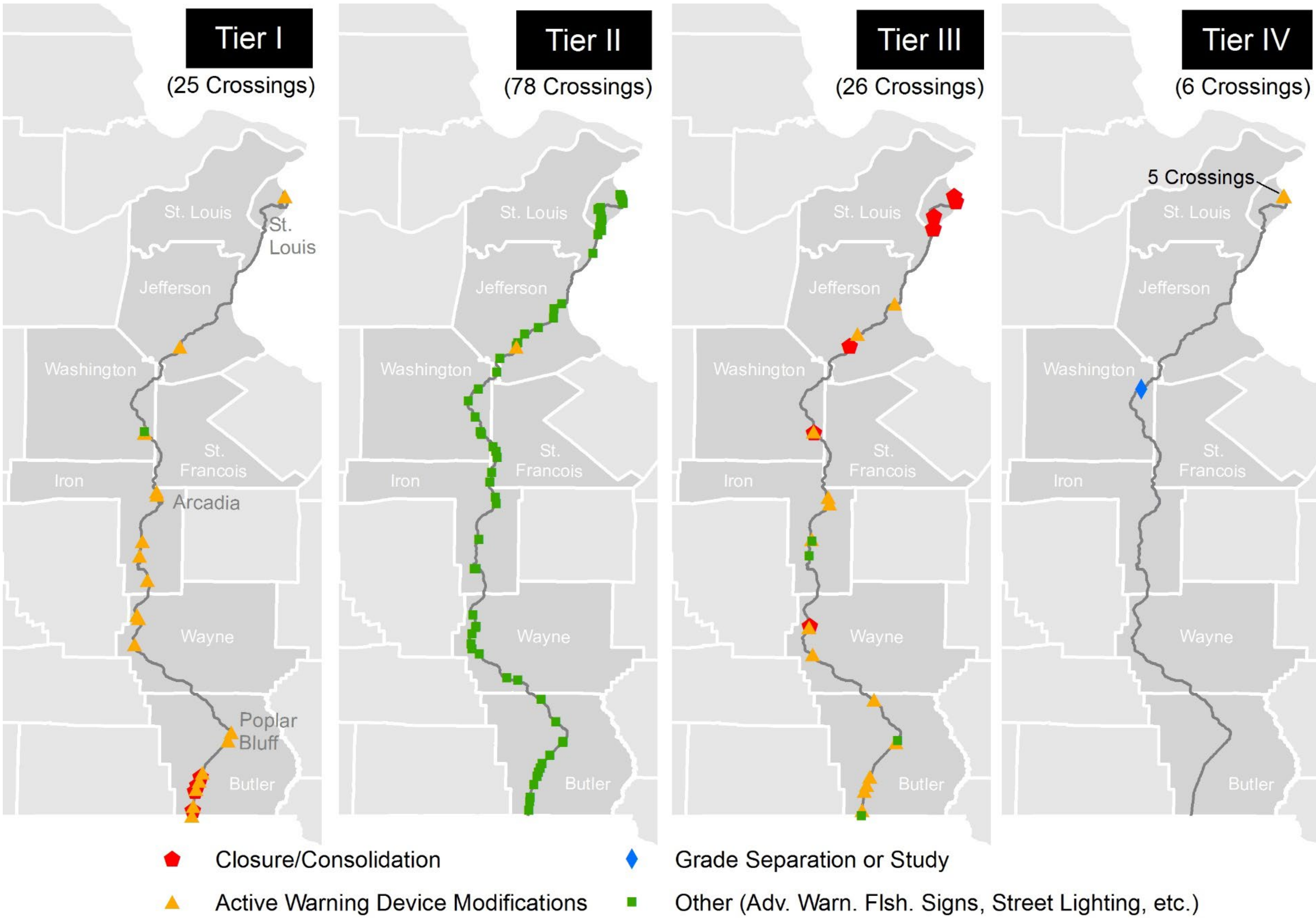
Tier III

Tier III includes crossings with more complex improvements that aren't included in the other three Tiers (see Table 5 for categories assigned to Tier III). Tier III improvements have been identified at 26 crossings, at a cost of approximately $8.9 million. Tier III improvement are intended to be completed within 36 months.

Tier IV

Tier IV improvements included grade separation and studies – items that may take more time to prepare and implement. Additional studies and projects could be identified for this Tier following the completion of this report. Six (6) crossings have been identified for Tier IV improvements: Crossing 446438Y, in the city of Cadet may require grade-separation and corresponding grade separation study. The study and grade-separation are estimated to cost over $5 million. Five (5) crossings in St. Louis, starting at crossing 803353G and ending at 803349S have been identified to warrant further site condition study.

Figure 16. Crossings with Improvements per Tier



SUMMARY OF IMPROVEMENTS

In total, 284 improvements have been recommended along the Texas Eagle corridor. Note that more than one improvement type can be recommended per crossing (and per tier), which is why the total number of improvements greatly exceeds the number of crossings. A summary of improvements can be seen below in Table 6. The majority of improvements, 203 of them, are categorized as Tier II. The most common improvements are signage (standard and flashing), pavement markings, and illumination. As indicated in the previous section on tiering approach, the Texas Eagle corridor has several public passive crossings, resulting in 46 Tier I recommendations. There are 12 crossings in total that have been recommended for closure, which represents 12% of all crossings in the corridor. While there is only a single recommended grade separation, this will represent a large portion of proposed costs, as discussed in the next section, "*Costs*."

Table 6. Summary of Recommended Improvements by Tier

Improvement	Tier I	Tier II	Tier III	Tier IV	Total
Pavement Markings		42			**42**
Advance Warning Flashing Signs	5	68			**73**
Advance Warning Signs		48			**48**
Illumination	15	43			**58**
Gates and Lights	17		12		**29**
Flashing Lights	2		1		**3**
Blank-Out Preemption Sign		1			**1**
Vertical Re-Profiling			3		**3**
Horizontal Re-Alignment			1		**1**
Automatic Pedestrian Gates	1		2		**3**
Extend Sidewalks		1			**1**
Relocate Gates and Lights	1				**1**
Drainage Pipe			1		**1**
Grade Separation				1	**1**
Grade Separation Study				1	**1**
Corridor Study				1	**1**
High-Security Gates	1				**1**
Closure/Consolidation	4		8		**12**

Costs

The total estimated cost for all recommended Texas Eagle corridor improvements is roughly $35.5 million. A summary of estimated costs by improvement and tier is given in Table 7. A contingency of 30 percent has been assumed, though unit costs provided in the next sub-section are provided without contingency. The cost for Tier I is estimated to be $10.9 million, Tier II to be nearly $2.1 million, Tier III to be over $8.9 million, and Tier IV, which is reserved for the grade separation study/construction and the signal study to be nearly $13.6 million. The estimated cost for Tiers I-III is nearly $22 million.

Nearly 40 percent of the total estimated $35.5 million cost can be attributed to the proposed grade separation and accompanying engineering study, the cost of which would be significantly refined. Items with costs above $1,000,000 are illumination, automatic vehicle gates, flashing lights, automatic pedestrian gates, and grade separation. Items with costs between $500,000-$999,999 are advanced warning flashing signs and vertical re-profiling.

Table 7. Summary of Estimated Costs by Tier (including contingency)

Improvement	Tier I	Tier II	Tier III	Tier IV	Total
Pavement Markings		$215,800			**$215,800**
Advance Warning Flashing Signs	$26,000	$561,600			**$587,600**
Advance Warning Signs		$99,450			**$99,450**
Illumination	$390,000	$1,118,000			**$1,508,000**
Gates and Lights	$8,840,000		$6,240,000		**$15,080,000**
Flashing Lights	$1,040,000		$520,000		**$1,560,000**
Blank-Out Preemption Sign		$97,500			**$97,500**
Vertical Re-Profiling			$975,000		**$975,000**
Horizontal Re-Alignment			$80,600		**$80,600**
Automatic Pedestrian Gates	$260,000		$780,000		**$1,040,000**
Extend Sidewalks		$10,920			**$10,920**
Relocate Gates and Lights	$130,000				**$130,000**
Drainage pipe(s)			$5,200		**$5,200**
Grade Separation				$13,000,000	**$13,000,000**
Grade Separation Study				$455,000	**$455,000**
Corridor Study				$130,005	**$130,005**
High-Security Gates	$13,000				**$13,000**
Closure/Consolidation	$156,000		$312,000		**$468,000**
Total	**$10,855,000**	**$2,103,270**	**$8,912,800**	**$13,585,005**	**$35,456,075**

Typically, improvements can be thought of as cumulative, although this is not always the case. For example, in some cases closure was considered as an option, but so were improvements that would be mutually exclusive with a closure. Another common example of non-cumulative improvement recommendations is signage; no crossing will have both flashing and non-flashing signage installed. Aside from the high variability of the construction of a potential grade separation, the total estimated cost can be thought of as an upper-bound.

UNIT COSTS

Estimated unit costs were developed using industry standards, engineering practice experience, and recently completed projects. A summary of pre-contingency unit costs is given below in Table 8. As previously mentioned, the cost with the highest potential variance is the grade separation construction. A realistic range is estimated to be $5-20 million. For the sole grade separation recommendation at crossing 446438Y in the City of Cadet, a value of $5 million dollars has been used per previous MoDOT cost estimation.

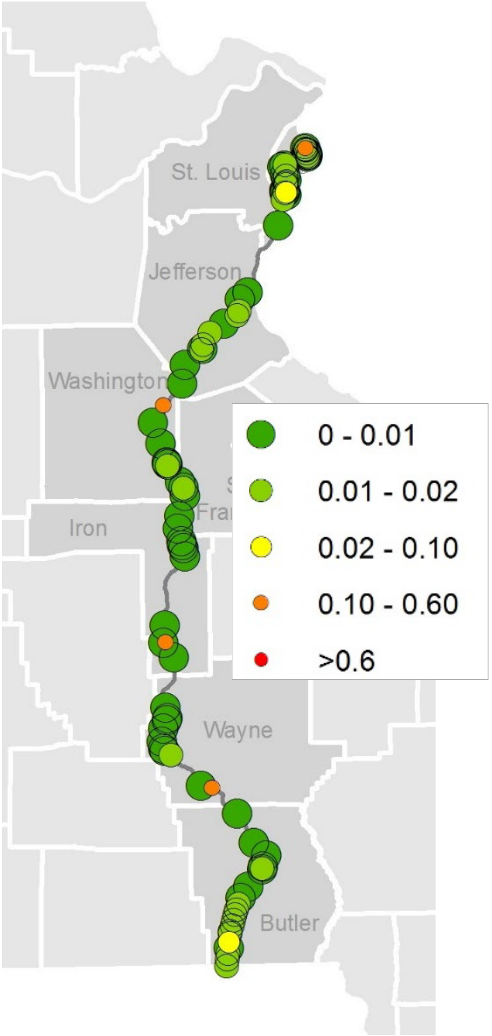
Table 8. Summary of Unit Costs (less contingency)

Improvement	Unit	Unit Cost
Pavement Markings	EA	$2,000
Advance Warning Flashing Sign	EA	$2,000
Advance Warning Sign	EA	$500
Illumination	EA	$10,000
Automatic Vehicle Gates	EA	$200,000
Flashing Lights	EA	$200,000
Blank-Out Preemption Sign	EA	$75,000
Vertical Re-Profiling	EA	$50,000
Horizontal Re-Alignment	LF	$400
Non-Traversable Median	LF	$300
Automatic Pedestrian Gates	EA	$100,000
Extend Sidewalks	SY	$70
Relocate Gates	EA	$100,000
Drainage Pipe(s)	LF	$100
Grade Separation	EA	$10,000,000
Grade Separation Study	EA	$350,000
High-Security Gates	EA	$10,000
Closure/Consolidation	LS	$30,000
Corridor Study	EA	$100,000

Safety Benefits

The primary benefits expected from the recommended improvements are reductions in the risk and expected collisions throughout the corridor. This section quantifies the impacts of these benefits using standard industry methods. Figure 17 shows the predicted annual grade-crossing incidents at each grade crossing on the corridor (in their current configuration). As can be seen in comparison with Figure 5 (which shows historical incidents), the model predictions are heavily influenced by areas that have previous incidents. All crossings with a prediction above 0.10 have at least one incident in the historical five-year period. Thus, the crossings with predictions in a range of 0.02 – 0.10 are also of interest, in that they are predicted to experience more incidents than most of the other crossings, but do not have an incident history. These crash predictions were taken into account in developing improvement recommendations.

Figure 17. Estimated Five-Year Incidents (FRA Model)



FRA RISK MODELLING AND CRASH MODIFICATION FACTORS

The risk modeling used in this study is based on the FRA's Accident Prediction and Severity (APS) model and on the application of industry standard crash modification factors. The APS model parameters include number of daily trains, average annual daily traffic, maximum train speed, road surface, historical crash history, and warning devices present. The model yields the annual probability of an incident occurring at a crossing; further analysis can predict the severity of a potential incident. Because many of the proposed improvements are not accounted for in the APS model (signing, illumination, roadway improvements, etc.), Crash Modification Factors (CMFs) – commonly used in highway safety analysis – can be applied to the APS model's outputs to refine risk predictions. Note that while many improvement types such as active warning device installation and median installation are readily quantifiable, other improvements such as advance warning flashing signs and roadway vertical alignment work are not quantified in existing safety literature. Table 9 provides additional detail regarding the risk reduction impacts of each improvement type used in this study.

Table 9. Risk Reduction by Recommended Improvement

Improvement	Risk Reduction	Notes
Base Risk Reduction (Warning Device Change)		
Passive → Gates	75 - 86%	Varies based on trains/day and track configuration (See Table 3)
Lights → Gates	65 - 89%	Varies based on trains/day and track configuration (See Table 3)
Any → Closure	100%	In practice, crossing closure will result in some traffic being diverted to adjacent crossings, marginally increasing the risk at those crossings. For simplicity, this study does not account for this impact.
Grade Separation	100%	
High Security Gates	100%	Assumes that crossings with high security gates will be effectively closed except during emergency situations.
Non-Traversable Medians	80%	Reduction based on assumption of medians being a minimum of 60-100' in length
Illumination	5%	Limited literature available regarding efficacy of this improvement. The 5% reduction was selected using engineering judgement and available data.
Advance Warning Flashing Signs (AWFS)	5%	Limited literature available regarding efficacy of this improvement. The 5% reduction was selected using engineering judgement and available data.

The following improvement types were assumed to have no quantifiable risk reduction impact due to limited safety literature and safety studies. However, in practice, these improvements are expected to improve safety compared to existing risk levels:

- Signal preemption
- Additional pairs of flashing warning devices and sidelights
- Standard advance warning signs and pavement markings
- Horizontal and vertical roadway approach modifications

CORRIDOR RISK REDUCTION RESULTS

The estimated risk reduction impacts of the proposed safety improvements are summarized in Table 10. Based on the FRA APS model, the base estimated annual number of incidents in the Texas Eagle Corridor is 0.59. As shown earlier in Table 7, upgrades to warning devices results in a predicted 75-86 percent reduction when upgrading passive crossings to automatic gates, a 65-89 percent reduction after upgrading flashing lights to automatic gates, and 100 percent reduction after closing a crossing. Grade separation and high-security gates function as quasi-closures and also reduce risk by 100 percent.

Table 10. Corridor Risk Reduction

Tier	Risk Reduction	Estimated Annual Incidents	Estimated Annual Crash Reduction benefit
Base	-	0.59	-
I	10.3%	0.34	$433,812
II	11.9%	0.30	$503,551
III	12.4%	0.29	$524,465

The reduction in estimated crossing risk ranges from 10.3 percent in Tier I to 12.4 percent in Tier III. The table also includes estimates of the annual benefit of reduced crashes. This analysis used the recommended monetized values for crashes found in the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Program*, January 2023. That document recommends values of $13,046,800 for fatal crashes, $307,800 for injury crashes, and $4,800 for property damage only crashes. These values were applied to the estimated distribution of fatal (13 percent), injury (28 percent), and property damage only (PDO) (59 percent) crashes in the Texas Eagle corridor based on the FRA APS model results. Applying these values resulted in an average cost per crash of $1,768,300. The implementation of the proposed safety improvements results in benefits ranging from $433,812 per year for Tier I to $524,465 for all improvements in Tiers I, II, and III.

While predicted risk reduction has been well-studied for many of the types of improvements recommended in this study, especially changes in traffic control devices (e.g., passive to gates), traffic safety is a relatively new field for which data and correlations are still being developed. Thus, some of the improvements considered in this study – most notably vertical re-profiling, pedestrian gates, and horizontal re-alignment – do not currently have well-established industry standards for predicted risk reductions. It can reasonably be assumed that the addition of some proposed improvements will reduce risk, though risk-reduction data is not available. Therefore, for many of the crossings evaluated in this study, reported risk reductions serve as "lower bounds", and greater reductions are potentially possible.

Although risk reductions aren't quantified for some of the recommendations in this document, it is reasonable to expect some level of reduction in risk from all recommended improvements. For example, roadway improvements can either improve visibility or eliminate common risks altogether; vertical re-profiling can eliminate the risk of trucks and trailers high-centering in the crossing; horizontal re-alignment is known to improve drivers' visibility; and non-traversable medians can eliminate the risk of driving around lowered gates. Advance warning signs, blank-out signs, and pavement markings alert and prepare drivers to expect crossings. Traffic preemption at signalized intersections can give drivers more time to clear crossings and yield right-of-way to approaching trains.

Next Steps

A number of steps will be required to finalize and implement the recommendations made as part of this study. In addition, necessary public engagement will occur during project development but will not affect the findings of this study. The following bullets summarize some of the key steps and responsibilities from the various grade crossing safety partners involved in the study:

- **Tier I Field Diagnostic Evaluations (June 2023):** As of the writing of this report, field diagnostic evaluations are currently underway for the Tier I crossings in the Texas Eagle corridor. The purpose of the diagnostic evaluations is to review the recommended safety improvements with representatives from MoDOT, UP, and local road authorities. These reviews will help to identify potential cost impacts of the safety improvement, specifically those related to railroad signal infrastructure. Due to the accelerated nature of this study, the results of the Tier I Field Diagnostic Meetings could not be incorporated into this report.
- **Planning and Construction Coordination for the Tier I Safety Improvements (Summer 2023 – Spring 2024):** Coordination with the road authorities responsible for maintenance of the crossing roadway approaches will be necessary for improvement construction. Specifically, the more major improvement recommendations such as closures will need to be coordinated before implementation is possible.
- **Tier II-III Diagnostics and Coordination (Fall 2023 – 2024):** While the immediate focus has been on the Tier I crossings in the corridor, field diagnostic meetings and construction coordination similar to the activities described in the previous two bullets will need to be coordinated and facilitated for the remaining safety improvement recommendations.
- **Coordination of Planning and Study Activities for Tier IV Improvement Options (2024 – 2026+):** The Tier IV recommendations include longer-term recommendations that will require additional study or design coordination. For the Texas Eagle Runner corridor, the only Tier IV recommendations are a potential grade separation of Highway 47 near Cadet, MO and smaller corridor study of five (5) crossings in St. Louis, starting at 803353G and ending at 803349S. These recommendations will require additional study to determine the feasibility of such an improvement and the development of design options that identify the potential impacts to surrounding properties.